

Smart IoT-Based Power Socket Control & Energy Monitoring System.

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Abstract - Electrical power sockets in college laboratories and institutional environments operate as passive, unmonitored endpoints with no capability for remote control, real-time measurement, or automated scheduling. This paper presents the design and implementation of an IoT-based Smart Lab Bench — an intelligent power management system built around the ESP32 microcontroller. The proposed system enables authorised users to control individual sockets remotely through a mobile application, monitor live voltage, current, and energy consumption, receive instant alerts during overload conditions, and set automated shutdown schedules based on operational hours. Hardware components include a voltage measurement module, relay module, PIR motion sensor, and voltage breaker, coordinated through the ESP32 and connected to the Blynk cloud platform. The system is projected to reduce idle energy consumption by 15–30% in laboratory environments while improving electrical safety through automated overload protection.

Key Words: Internet of Things (IoT), Smart Power Socket, ESP32 Microcontroller, Remote Device Control, Laboratory Automation, Voltage and Current Sensors, Relay-Based Power Control, Blynk Platform.

1.INTRODUCTION

1.1 Industry Domain Background

The rapid growth of smart infrastructure and the Internet of Things (IoT) has created opportunities to modernize energy management in institutional and industrial settings. However, most electrical power systems — especially in labs, campuses, and factories — still rely on manual or timer-based socket controls, limiting real-time oversight and adaptability.

1.2 Importance of the Problem

Inefficient power usage leads to significant energy wastage, increased electricity costs, and safety risks

from unattended equipment. The inability to monitor consumption or control devices remotely hinders operational efficiency and sustainability efforts in environments where safety and resource conservation are priorities.

1.3 Project Overview

This project develops an IoT-based smart socket system that enables users to remotely control electrical outlets via a mobile application. The system provides real-time energy monitoring, automated shutdown schedules, and alert notifications, aiming to enhance energy safety, reduce wastage, and support smarter facility management in colleges, labs, and industrial environments.

2. LITERATURE REVIEW

Overheating and energy waste in electrical systems have driven extensive research into IoT-based monitoring solutions. Many studies confirm that continuous power monitoring is essential for protecting electrical systems and improving operational reliability.

[1].Techspot Infotech LLP developed an ESP32-based smart socket system using Blynk/MQTT for cloud integration and MIT App Inventor for the mobile interface. The system demonstrated automated lab shutdown scheduling and overload alert generation, but remained network-dependent and produced estimated rather than precise energy readings

[2].Bajracharya et al. (2025) presented a smart multiplug using the ESP32 with ACS712 current sensors and DHT22 temperature sensors, achieving ± 0.08 A current accuracy and automatic cutoff at 10 A and 70°C. However, the system lacked local Bluetooth fallback and did not account for transient voltage spikes

[3].Liang and Yu (2015) demonstrated a low-cost smart socket for real-time appliance monitoring via IEEE Smart Grid platforms. While effective for monitoring, the system lacked mobile app support and relied on dated communication protocols

[4].Kumar and Jasuja (2017) deployed IoT-based energy monitoring across a campus environment, achieving an 18–22% reduction in energy consumption. The system incurred high infrastructure costs and lacked relay-level socket control

2.1 Problem definition

Traditional electrical panels and power sockets do not provide real-time monitoring of energy consumption. Appliances left energised beyond operational hours — due to human oversight — cause persistent energy wastage and elevated electrical hazard risk.

Conventional sockets are entirely passive: they offer no remote control capability, no consumption visibility, and no automated safety response when load thresholds are exceeded. There is therefore a clear need for an intelligent solution that automates control, provides real-time oversight, and eliminates dependence on human memory to ensure energy efficiency and electrical safety.

2.2 Objectives of the project

- To enable remote control of each socket through a mobile application.
- To monitor real-time voltage, current, and energy usage per socket.
- To provide automated shutdown after designated lab hours.
- To improve electrical safety through overload protection and alerts.
- To develop a low-cost, scalable smart automation solution.

2.3 Methodology

The Smart Lab Bench system monitors power consumption and controls electrical sockets through a four-layer architecture: mobile application, cloud server, ESP32 embedded controller, and physical load layer.

The system operates on a regulated 5 V power supply. The ESP32 microcontroller continuously reads voltage and current from the measurement module, transmitting data via built-in Wi-Fi to the Blynk cloud platform where it is stored and displayed on the mobile application in real time.

When a user issues a command — to switch a socket, set a shutdown schedule, or define an alert threshold — the instruction routes from the app to the cloud and is relayed to the ESP32, which actuates the relay accordingly.

In the event of an overload condition, the system autonomously disconnects the load and sends a push notification to the registered mobile device. The PIR motion sensor allows sockets to deactivate automatically when no occupancy is detected beyond a defined period.

Table 1: Hardware Components

Sr.	Component	Description
1	Power Supply (5V)	Regulated supply for ESP32 and peripherals
2	ESP32 Microcontroller	Central controller with built-in Wi-Fi/BLE
3	PIR Motion Sensor	Occupancy detection for auto-shutdown
4	Voltage Meas. Module	Live voltage monitoring at each socket
5	Relay Module	Electronic switch for load control

2.4 Block Diagram

The hardware architecture is shown in Fig. 1. AC mains power enters a voltage breaker for primary overvoltage protection, then feeds a voltage measurement module and power supply unit. The ESP32 sits at the centre, receiving sensor data, issuing relay commands, and transmitting all readings to the Blynk cloud platform via its onboard Wi-Fi interface.

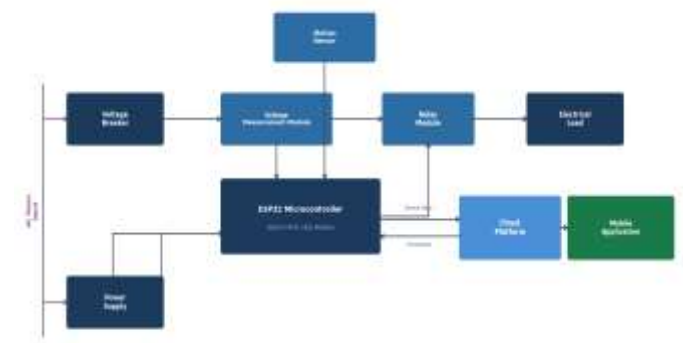


Fig. 1. Hardware Block Diagram — A Smart IoT-Based power socket control & energy monitoring system

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2.5 Advantages

1 Energy Efficiency

- Real-time power monitoring identifies energy-intensive devices and wasteful patterns.
- Automated scheduling eliminates idle consumption projected savings.
- Peak load management optimises electricity usage across lab sessions.

2 Enhanced Safety

- Automatic overload protection disconnects circuits before fault conditions escalate.
- Remote emergency cutoff allows staff to deactivate equipment without physical access.
- Continuous current monitoring provides early warning of developing faults.

3 Operational Convenience

- Full socket control from any location through the mobile application.
- Centralised management of multiple sockets through a single interface.

2.6 Applications

- Education: Automated post-session shutdown in electronics and computer labs.
- Industry: Equipment runtime tracking and automated safety cutoffs for machinery.
- Healthcare: Scheduled activation of medical equipment in clinical settings.
- Commercial: Office automation, retail lighting control, hotel energy management.
- Agriculture: Irrigation pump scheduling and greenhouse environment control.

2.7 Expected Outcomes

- Fully operational smart socket system with real-time mobile control and energy monitoring.
- 15–30% quantifiable reduction in idle energy consumption.
- Automated schedule-based shutdown for sockets across laboratory environments.
- Overload detection and alert notification to prevent equipment damage.
- Scalable, modular hardware design deployable without replacing existing infrastructure.

3. CONCLUSION

The IoT-based Smart Lab Bench successfully creates an intelligent energy management system enabling remote control, real-time monitoring, and automated scheduling of electrical devices. The system enhances safety through overload protection, reduces energy waste by eliminating standby power, and provides valuable consumption insights. Its user-friendly mobile interface and scalable design make it particularly suitable for colleges and labs. Future enhancements may include AI-driven scheduling, voice control integration, and blockchain-enabled energy sharing within campus microgrids.

ACKNOWLEDGEMENT

The authors express sincere gratitude to Mr. B. D. Shelke for expert guidance and continuous support throughout this project. They also acknowledge the Department of Electronics & Telecommunication Engineering and the management of Adarsh Institute of Technology & Research Centre, Vita, for providing the necessary resources and laboratory facilities.

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